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BULLETIN

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AMERICAN PHYSICAL SOCIETY

PROGRAM

FOR THE

NEW YORK MEETING

FEBRUARY 22–23, 1935

JOINT MEETING

WITH THE

OPTICAL SOCIETY OF AMERICA

COLUMBIA UNIVERSITY

For Program of session of the Optical Society see Pages 5 to 9
For Program of sessions of the Physical Society see Pages 10 to 19

PUBLISHED BY THE AMERICAN PHYSICAL SOCIETY
SEVEN ISSUES EACH YEAR

The American Physical Society

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of the

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FEBRUARY 5, 1935 Vol. 10, No. 1

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

NEW YORK MEETING, FEBRUARY 22–23, 1935

JOINT MEETING WITH THE OPTICAL SOCIETY OF AMERICA

THE 197th regular meeting of the American Physical Society will be held in New York City on Friday and Saturday, February 22–23, 1935 as a joint meeting with the Optical Society of America. The sessions on Friday and Saturday for both the Physical Society and the Optical Society will be held at Columbia University in the Physics Laboratories on 120th Street east of Broadway (entrance at 119th Street and Broadway).

Joint Session. On Friday morning at 9:30 o'clock there will be a joint session of the two Societies in Room 401. This session will be a symposium on *Atmospheric Optics*.

Regular Sessions. For details of the regular sessions of contributed papers see the Calendar on the following page.

Dinner. On Friday evening at 6:30 o'clock there will be a joint dinner for the members of the two Societies and their friends at the Columbia University Men's Faculty Club (corner 117th Street and Morningside Drive). The President of the Physical Society, Professor R. W. Wood of Johns Hopkins University, will preside. The price of the dinner will be $1.25 per plate. Tickets will be on sale at the Physics Laboratories, Columbia University. Reservations should be made as early as possible and not later than Friday at 3 P.M. The time of the dinner is set early so that those who wish may leave in time for other evening appointments.

Luncheon. On Friday and Saturday luncheon may be had at the Columbia University Men's Faculty Club. Further announcement will be made at the Friday and Saturday sessions.

Meeting of the Metropolitan Section. The second meeting of the Metropolitan Section for the season 1934–1935 will be held on Friday, March 22, in the Physics Laboratories of Columbia University. The program will be as follows:

Afternoon session:

Prediction of Atomic Energy States. R. F. BACHER.
Measurement of Nuclear Magnetic Moments from Hyperfine Structure Data. L. P. GRANATH.
Nuclear Moments from Molecular Beams. I. I. RABI.
Isotope Effect in Polyatomic Molecules. W. S. BENEDICT.

Evening session:

Methods of Separation of Isotopes. H. C. UREY.

GENERAL RULES RELATING TO PAPERS

Only those titles of papers shall be listed on the preliminary program of a meeting of the Society for which abstracts ready for publication are in the hands of the Secretary.

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program. (A paper presented by two or more authors is assigned to the first named author.) Papers received after the program has been printed will be placed in the supplementary program.

All supplementary papers will be grouped according to subject matter and will be called for at their appropriate sessions only, these sessions to be designated on the program. The presiding officer may assign a reduced time to

these papers or may in his discretion call for them to be read by title only.

Except by special vote of the Society, the maximum allowance of time for the presentation of a paper shall be ten minutes. The presiding officer shall enforce this rule.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction the abstracts will be published in an early number of the *Physical Review*. Authors should send corrections to the Editorial Secretary, The American Institute of Physics, Incorporated, 11 East 38th Street, New York, N. Y.

Other meetings for the current season are as follows:

198. April 25–27, 1935. Washington, D. C.
199. June 24–28, 1935. Los Angeles, California.
200. June, 1935. Minneapolis, Minnesota.
201. November 29–30, 1935. Baltimore, Maryland.
202. December, 1935. Pacific Coast Section.
203. December, 1935. St. Louis, Missouri. Annual Meeting.

W. L. SEVERINGHAUS, *Secretary*,
Columbia University, New York, N. Y.

February 5, 1935.

CALENDAR

Friday morning

9:30 o'clock: Physics Laboratories: Room 401: Joint session of the two Societies: Symposium on *Atmospheric Optics*. Papers 1–5. See page 5.

Friday afternoon

2:00 o'clock: Physics Laboratories: Room 428: Optical Society Papers 6–9. See page 5.

2:00 o'clock: Physics Laboratories: Room 401: Physical Society Papers 6–14. See pages 10–12.

4:00 o'clock: Physics Laboratories: Room 818: Meeting of the Council of the Physical Society.

Friday evening

6:30 o'clock: Columbia University Men's Faculty Club: Joint dinner of the two Societies.

8:15 o'clock: Physics Laboratories: Room 401: Public Lecture on *The Optical Phenomena of Clouds* by W. J. HUMPHREYS, *U. S. Weather Bureau*.

Saturday morning

10:00 o'clock: Physics Laboratories: Room 428: Optical Society Papers 10–14. See pages 6–7.

10:00 o'clock: Physics Laboratories: Room 401: Physical Society Papers 15–21. See pages 12–14.

10:00 o'clock: Physics Laboratories: Room 329: Physical Society Papers 22–28. See pages 14–15.

Saturday afternoon

2:00 o'clock: Physics Laboratories: Room 428: Optical Society Papers 15–20. See pages 7–9.

2:00 o'clock: Physics Laboratories: Room 401: Physical Society Papers 29–36. See pages 15–17.

2:00 o'clock: Physics Laboratories: Room 329: Physical Society Papers 37–44. See pages 17–19.

THE OPTICAL SOCIETY OF AMERICA

OFFICERS

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PROGRAM

FRIDAY, FEBRUARY 22 AT 9:30 O'CLOCK

Room 401

Joint Session of the American Physical Society and the Optical Society of America

SYMPOSIUM ON ATMOSPHERIC OPTICS

1. **Introduction.** BRIAN O'BRIEN, *Institute of Applied Optics, University of Rochester.*
2. **The Geometrical Theory of Halos.** EDGAR W. WOOLARD, *U. S. Weather Bureau.*
3. **Astronomical Seeing.** J. A. ANDERSON, *Mt. Wilson Observatory.*
4. **Distribution of Atmospheric Ozone.** R. LADENBURG, *Princeton University.*
5. **Light Absorption in the Atmosphere and its Photo-Chemistry.** OLIVER R. WULF, *Bureau of Chemistry and Soils.*

FRIDAY, FEBRUARY 22 AT 2:00 O'CLOCK

Room 428

INVITED PAPERS ON ATMOSPHERIC OPTICS

(For simultaneous session of the Physical Society, Room 401, see Program, pages 10–12.)

6. **Scattering of Light by Atmospheric Particles.** J. A. STRATTON, *Massachusetts Institute of Technology.*
7. **Attenuation of Light in the Lower Atmosphere.** E. O. HULBURT, *Naval Research Laboratory.*
8. **Visibility of Signals Through Fog.** GJON MILI, *Westinghouse Lamp Company.*
9. **Atmospheric Optics in Aviation Lighting.** F. C. BRECKENRIDGE, *National Bureau of Standards.*

FRIDAY EVENING AT 8:15 O'CLOCK

Room 401

Public Lecture

on

The Optical Phenomena of Clouds

BY W. J. HUMPHREYS, *U. S. Weather Bureau*

SATURDAY, FEBRUARY 23 AT 10:00 O'CLOCK

Room 428

Contributed Papers

(For simultaneous sessions of the Physical Society, Rooms 401 and 329, see Program, pages 12–15.)

10. Estimation of Chromaticity Differences and Nearest Color Temperature on the Standard 1931 I.C.I. Colorimetric Coordinate System. DEANE B. JUDD, *National Bureau of Standards.* (10 minutes.)

A Maxwell triangle yielding uniform chromaticity scales has been derived[1] by a trial-and-error method from comparison with experimental data on chromaticity sensibility. On this triangle the length of any line is a close measure of the chromaticity difference between the stimuli represented at the extremes of the line. To show the relative distortion between the uniform-chromaticity-scale triangle and the standard 1931 I.C.I. colorimetric coordinate system,[2] a group of thirty equal tangent circles on the former triangle have been transferred to the standard system where they appear as ellipses of various sizes, eccentricities, and orientations. A plot of these ellipses on the (x, y)-plot of the standard system assists in the estimation of chromaticity differences from trilinear coordinates on the standard system.

On the uniform-chromaticity-scale triangle the method for estimating nearest color temperature for a neighboring non-Planckian color stimulus is to draw the normal to the Planckian locus through the point representing the neighboring stimulus. The intersection of this normal with the Planckian locus gives the best estimate so far possible of the nearest color temperature. To facilitate carrying out this estimate on the standard coordinate system, a large number of the normals on the equal-chromaticity-scale triangle have been transferred to the standard system where they are, of course, no longer normal to the Planckian locus. These transferred normals drawn on the (x, y)-plot of the standard colorimetric coordinate system permit nearest color temperature to be read directly from the trilinear coordinates of the non-Planckian stimulus without the intermediate step of transforming these coordinates to the equal-chromaticity-scale system. Values of nearest color temperature by this method agree well with correlated color temperature by the Davis method[3] up to 3000°K but depart somewhat at higher temperatures.

[1] Judd, *A Maxwell Triangle Yielding Uniform Chromaticity Scales*, J. O. S. A. **24**, 163 (1934).
[2] Judd, *The 1931 I. C. I. Standard Observer and Coordinate System for Colorimetry*, J. O. S. A. **23**, 359 (1933).
[3] Davis, *A Correlated Color Temperature for Illuminants*, Bur. Standards J. Research **7**, 659 (1931).

11. Maximum Visual Reflectance of a Surface having a Given Chromaticity. DAVID L. MACADAM, *Massachusetts Institute of Technology.* (10 minutes.)

Any reflecting surface is characterized by a spectral reflectance curve, the values of reflectance lying between 0 percent and 100 percent. From the spectral reflectance curve, it is possible to compute the dominant wavelength, purity and relative brightness for a given source and observer. In this paper an investigation has been made of the maximum brightness that is possible for a given dominant wavelength and purity, assuming Illuminant C and the I.C.I. observer. By plotting maximum brightness vertically from each point in the I.C.I. triangle, a surface is secured which bounds a volume containing all the colors that are obtainable on a reflecting surface. This may be regarded as the color solid inherent in the I.C.I. data and, unlike previous color solids, does not depend upon the pigments that are available at present.

12. Critical Fusion Frequency in Different Spectral Regions. SELIG HECHT AND SIMON SHLAER, *Columbia University.* (20 minutes.)

In continuing our flicker investigations, we have improved the optical system so as to yield (a) a maximum brightness of 100,000 millilamberts, (b) a measuring field of 40° diameter, and (c) a fixation point of easily variable intensity and position.

Our previous measurements showed that the relation of critical frequency to intensity falls into two clearly divisible sections: a low intensity one, in which the critical frequency increases with intensity and reaches a maximum, maintained as a plateau, and following this a high region which also varies with intensity. The tentative identification of these sections as representing rod and cone functions, respectively, is now confirmed by measurements with different parts of the spectrum.

Using a 19° flickering area, centrally fixated, and surrounded by a non-flickering field 40° in diameter, we find that going from blue to red the cone portion remains essentially the same for all colors. The rod portion, however, suffers two changes. First, the extent of the intensity range decreases from four and a half log units in the blue to less than one log unit in the red, a reduction of 1000 to 1. This change in intensity range for different parts of the spectrum is easily understandable in terms of the photochromatic interval. Second, the maximum plateau value of the fusion frequency varies with λ. The plateau is highest (14.5 cycles per second) for the green; it decreases slightly toward the blue (12.6), and sharply to the yellow (11.5) and to the red (7.9).

This change of the maximum suggests a specific effect of λ as opposed to a mere difference in absorption such as would be expected with a single photosensitive substance like visual purple, in which all wavelengths presumably produce the same effect provided their intensities are large enough. Judged by sensation alone, the effect here is colorless and identical for all λ values; judged by critical fusion frequency, each portion of the spectrum produces a different effect.

The present paper will appear in full in the Journal of General Physiology.

13. Area and Critical Fusion Frequency of Flicker. SELIG HECHT AND EMIL L. SMITH, *Columbia University.* (25 minutes.)

In previous work on the influence of area on critical frequency of flicker, the measuring area corresponded to the total illuminated area on the retina. We have measured the influence of measuring area when the total illuminated area was constant at a diameter of 40°. Increasing area from 0.3° to 19.0° produces different effects on the low and on the high intensity portions. The extent of the low intensity portion increases from nothing up to 2° until it covers 3.75 log units at 19°, where most of it is plateau. Since this corresponds anatomically with the distribution of rods, this confirms the identification of the low intensity portion with rod function. The plateau maximum also increases with area.

The high intensity portion changes little with area. For S.H. it remains essentially constant, the maximum frequency varying haphazardly between 47 and 52. For E.L.S. the maximum increases with area. From 0.3° to 6.0°, an increase in area of 1 to 400, the maximum goes from 40 to 45 cycles per second; at 19° it is 58. The presence or absence of the correlation with area probably depends on the criterion for judging flicker disappearance. This influences the maximum, but not the shape of the curve.

A theoretical relationship between frequency and intensity appears in terms of concentration of photosensitive substance and products at the stationary state. The relations differ critically with the order of the light and dark reactions. For the rod data critical frequency is proportional directly to the photo-product concentration when both light and dark reactions are monomolecular, or to the square of the concentration when the light reaction is monomolecular and the dark bimolecular. For the cones the data show a proportionality between critical frequency and concentration when both light and dark reactions are bimolecular.

In the cone portion, indications appear of a possible double relationship between flicker and intensity. This is not due to an admixture of rods in the cone portion, because it shows in the smallest fields and cannot be separated out by using extremes of red and blue light.

The present paper will appear in full in the Journal of General Physiology.

14. Disk Colorimetry Information. DOROTHY NICKERSON, *Bureau of Agricultural Economics.* (10 minutes.)

For careful work with the disk method of colorimetry, one must have (1) information concerning the color temperature of illumination and (2) careful measurements of the papers used as standards with the instruments. The purpose of this paper is to provide a certain amount of information on each of these subjects.

(1) Color temperatures are given for lamp and filter combinations of available instruments.

(2) The notation of the Munsell system is useful in color specification. More information must be made available if the papers are to serve their full purpose. Various formulas, surrounded by appropriate precautions, developed and used for specific purposes will serve a useful purpose until such time as information is assembled to provide more accurate tables, charts, or formulas for conversion of disk areas to equally stepped scales of hue, brilliance and saturation. (The basis for such work has recently been completed in Professor Hardy's laboratory in spectral reflectance measurements for all of the Munsell colors.)

Meanwhile, it has been necessary to standardize certain Munsell colors. Tristimulus specifications for several Munsell papers under I.C.I. standard illuminants have been calculated from spectral reflectance measurements made at the National Bureau of Standards. In order to compare the order of difference due to different methods of computation, and the order of difference due to curves somewhat similar in spectral reflectance, with the order of difference important in color grading work, tristimulus computations have been made and are presented for purposes of comparison. Specifications are given for certain glossy papers under diffuse and 45° directional illumination. Specifications are given for colors made in the Munsell laboratory to match other colors, using different pigments.

The present paper will appear in full in the Journal of the Optical Society.

SATURDAY, FEBRUARY 23, AT 2:00 O'CLOCK

Room 428

Contributed Papers

(For simultaneous sessions of the Physical Society, Rooms 401 and 329, see Program, pages 15–19.)

15. Photographic Plates for Use in Spectroscopy and Astronomy, IV. C. E. KENNETH MEES, *Eastman Kodak Company.* (15 minutes.)

In addition to the types of emulsion used for spectroscopic plates, a new type has been made which, when sensitized for the infrared, has as much sensitivity as the Type I emulsion but shows a contrast and graininess corresponding to Type IV. In connection with this, a new nomenclature is introduced and the emulsion is termed Type 144.

As a result of a great advance in the production of polycarbocyanine dyes, it has been possible to revise and extend the sensitizing for the infrared.

A new sensitizing, Type M, has been introduced giving

a maximum of sensitivity at λ9300, and a pentacarbocyanine dye has been obtained which gives a maximum of sensitivity at λ10,900. Plates made with this dye, which are known as Type Z, enable the infrared to be photographed at least as far as λ12,000.

The present paper will appear in full in the Journal of the Optical Society; C. E. Kenneth Mees, J. Opt. Soc. Am. **21**, 753 (1931); **22**, 204 (1932); **23**, 229 (1933).

16. Anomalous Dispersion within Absorption Bands. A. H. PFUND, *Johns Hopkins University.* (10 minutes.)

Because of the great weakening of light, it is usually difficult to follow the dispersion of a substance through an absorption band. In previous work (Pfund, J. O. S. A. **24**, 121 (1934)) it has been shown that, by making use of diffraction bands, dispersion may be followed through an absorption band: the necessary condition for the production of sharp bands being that the intensity of the beam falling on the absorbing medium be sufficiently increased over that of the "other" beam that their intensities, upon interference, be the same. This principle is here applied to a Young's interference apparatus by means of which the dispersion of aniline violet, neodymium nitrate and gold is readily followed through the regions of absorption. It is shown that the above outlined procedure may be readily applied to the Michelson interferometer.

The present paper will appear in full in the Journal of the Optical Society.

17. Change in the Photoelectric Threshold of Thorium and Similar Metals by Oxygen. H. C. RENTSCHLER AND D. E. HENRY, *Westinghouse Lamp Company, Bloomfield, N. J.* (10 minutes.)

The use of silver oxide for producing caesium photoelectric cells of increased sensitivity is commonly known. Barium cells are generally prepared from barium oxide surfaces. An experiment will be described which shows that when a small amount of oxygen is introduced into a photo-cell with a clean surface of thorium the sensitivity is increased and the threshold is shifted towards the longer wavelength. This result is of importance in indicating the nature of the photo-active surface of these metals.

The present paper will appear in full in the Journal of the Optical Society.

18. A Photoelectric Colorimeter with Logarithmic Response. RALPH H. MÜLLER AND GILBERT F. KINNEY, *New York University.* (10 minutes.)

The photometric measurement of colored solutions which obey Beer's law is most conveniently represented by a semilogarithmic plot of transmittancy against concentration. This is always preferable to purely empirical calibration.[1] It is highly desirable, however, to have an instrument which is direct reading. Since the light intensity varies logarithmically with concentration, the photoelectric current can be fed into a vacuum-tube voltmeter having a logarithmic input characteristic. The plate current will then be a linear function of the concentration. This type of vacuum-tube voltmeter has been used extensively in the communication field.[2]

In applying it to colorimetry the conventional methods had to be modified somewhat. An RCA Type 6D6 tube is employed with a suitable biasing resistor in the cathode lead. Under the chosen conditions of operation a value for this resistor can be found which will yield a plate current varying as the logarithm of the input voltage over a limited but adequate range. This relationship never extends to zero plate current. For this reason it is necessary to balance out a portion of the plate current, giving, in effect, a suppressed-zero instrument. Advantage is taken of the suppressed-zero feature by using a sensitive meter in the plate circuit. The range of the photometer is extended by a choice of input resistors and the use of a multi-range meter in the plate circuit. The scales can be calibrated directly in concentration units. For automatic recording, as, for example, in following the course of rapid reactions, the direct reading feature is of distinct value.

The same result can be achieved in other ways. The open-circuit e.m.f. of a barrier-layer cell is a logarithmic function of the light intensity and can be employed in colorimetry.

The present paper will appear in full in the Review of Scientific Instruments.

[1] R. H. Müller, Mikrochemie **11**, 353 (1932).
[2] S. Ballentine, Electronics **1**, 472 (1931); J. Acous. Soc. Am. **5**, 10 (1933); F. V. Hunt, R. S. I. **4**, 672 (1934).

19. A Direct Reading Comparator for Spectra. L. G. HOXTON, *University of Virginia,* AND D. W. MANN, *Harvard University.* (20 minutes.)

This instrument is capable of reading off directly from the lines of a spectrogram to the divided head of a screw either wavelengths or wave-frequency numbers as desired. The degree of approximation is closer than that yielded by the Hartmann interpolation formula.

In effect the Hartmann formula is first mechanically realized through a principle of geometric projection, but by introducing an element of eccentricity with respect to the point of projection, the equivalent of a fourth constant in the formula is added. The instrument may then be adjusted to four known lines on the plate instead of three as would be the case in dealing with the formula.

One moving part, on an accurate pivot, consisting of two adjustable arms with straight edges, is interposed between the screw carriage and the plate carriage and, pressing against steel balls fixed to the two carriages, constitutes the transfer mechanism from screw to plate.

An example of the instrument will be shown. It was developed from a crude model described before the Society in 1929[1] and was built by the Mann Instrument Company of Cambridge, Massachusetts.

[1] L. G. Hoxton, J. O. S. A. and R. S. I. **18**, 443 (1929).

20. An Optical Device to Aid in Mapping from Photographs. O. M. MILLER, *American Geographical Society.* (15 minutes.)

The paper describes an optical device invented by the author to aid in the plotting of maps from photographs. It is the development of an idea first suggested by Deville[1] whereby an observer views directly through a half-silvered mirror an index mark attached to a plotting pencil moving

in the plane of the map and views by reflection from the mirror the photographic view set at its correct orientation to the map plane. An image of the real index mark is thus seen superimposed in the perspective view. This simple device is not practical in a precision instrument, due principally to the difficulty of keeping the moving index mark in focus to the observer while he is concentrating on details in the picture plane. The device as developed by the author succeeds in overcoming this difficulty of focus by the use of a pinhole mirror and a periscope. Thin pencils of rays from an illuminated moving index mark behind the mirror on passing through the pinhole are enveloped by corresponding reflected pencils from point images in the photograph. The periscope functions solely as a viewing apparatus whereby the eye is placed virtually at the perspective center of the set up, namely the pinhole.

An instrument for plotting planimetry from single oblique aerial photographs, which incorporates this device, is in use at the American Geographical Society, and the author hopes eventually to build a stereoscopic plotting machine on the same principle.

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[1] E. Deville, *On the Use of the Wheatstone Stereoscope in Photographic Surveying*, Trans. Roy. Soc. Canada **8**, 63–69 (1902). Also O. von Gruber, *Photogrammetry: Collected Lectures and Essays*, translated from the German original by G. T. McCaw and F. A. Cazalet, American Photographic Publishing Company, Boston, 1932.

PROGRAM

For Sessions of the American Physical Society

FRIDAY MORNING AT 9:30 O'CLOCK

Room 401

Joint Session of The American Physical Society
and The Optical Society of America

SYMPOSIUM
ON
ATMOSPHERIC OPTICS

Invited Papers

1. **Introduction.** BRIAN O'BRIEN, *Institute of Optics, University of Rochester.*
2. **The Geometrical Theory of Halos.** EDGAR W. WOOLARD, *U. S. Weather Bureau.*
3. **Astronomical Seeing.** J. A. ANDERSON, *Mt. Wilson Observatory.*
4. **Distribution of Atmospheric Ozone.** R. LADENBURG, *Princeton University.*
5. **Light Absorption in the Atmosphere and Its Photo-Chemistry.** OLIVER R. WULF, *Bureau of Chemistry and Soils.*

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Room 401

(For simultaneous session of the Optical Society, Room 428, see Program, page 5.)

Paper No. 13 will be read by title.

6. Electron Temperatures in Mercury Vapor Afterglow. R. H. RANDALL, *College of the City of New York,* AND HAROLD W. WEBB, *Columbia University.*—The time rate of decrease of electron temperature and concentration in a plasma free from external field has been studied in a stream of ionized vapor from a mercury arc flowing through a tube 30 cm long. The vapor velocity and density were determined from stroboscopic observations on the spacing of striations produced by an alternating voltage on a quenching grid and from measurements of the mass of streaming vapor. The computed pressure varied from 0.01 to 2 mm. A movable Langmuir prove was used to measure electron temperatures and concentrations at different points in the tube. Above approximately 2500°K the cooling of the electrons was apparently due largely to diffusion to the walls. The rate of cooling, at a given temperature, decreased with increased pressure. Below 2500°K the rate of cooling of the electrons rapidly fell to zero at a temperature considerably above the estimated gas temperature. The difference between this final constant temperature and the gas temperature was proportional to the pressure. To explain this final temperature level it is assumed that a process, depending upon recombination, tends to increase the electron temperature, balancing the normal cooling process.

7. The Anchored Mercury Pool Cathode Spot. LEWI TONKS, *General Electric Company.*—A large number of metals show the property, when partially immersed in the cathode pool of a mercury arc tube, of holding the cathode spot at the meniscus edge in the form of a fine luminous line. A necessary condition is wetting of the metal, which requires an extremely clean metal surface. No metal tried definitely fails to anchor the spot although the ease of anchoring varies from the noble metals, Pd, Pt, Ir, with which no precautions are necessary, to Ta, which is most difficult. The "cathode line" (anchored spot) attacks many of the metals, eating them away and depositing metal on the tube wall opposite the "line." Metals with melting points over 1900°C are immune to this erosion. A spectrogram of the C. L. showed great broadening of lines, possibly arising from extreme ion concentrations, and a continuum extending from the blue through the ultraviolet. The C. L. is not continuous but consists of rapidly and chaotically moving emitting areas. With Cb these are definitely points which carry 0.22 amp. each and move with the predominant velocity of 46 cm sec.$^{-1}$. With Mo, W, Ir the elementary emitting area is less definite.

8. The Role of Surface Instability in Electrical Discharges from Drops of Alcohol and Water in Air at Atmos-

pheric Pressure. JOHN ZELENY, *Yale University.*—A study of previous work on discharges from charged attached drops and from uncharged drops falling in electric fields shows that the surface electric intensities at these drops, when the discharges begin, satisfy the theoretical relations for surface instability. Glow discharges, if initially present, are conditioned by the surface deformation arising from instability. Experiments are described that indicate that the highly charged droplets ejected by an alcohol surface may have mobilities not much below those of normal air ions while such droplets coming from a water surface may have mobilities even greater than those of air ions. Calculations, by Stokes' law, show such large mobilities for both kinds of drops to be possible. Further experiments show that under certain conditions the whole discharge current from an alcohol drop is carried solely by droplets of the liquid resulting from surface instability, and under more restricted conditions the same may be true for a water drop.

9. Quenching of Cadmium Resonance Radiation (3261) by Hydrogen. HARRY C. LIPSON AND ALLAN C. G. MITCHELL, *New York University, University Heights.*—The quenching by hydrogen of the Cd resonance line 3261 was studied by illuminating two quartz resonance tubes by light from a hydrogen discharge tube containing Cd. One resonance tube contains Cd plus various amounts of hydrogen, while the other, which served as a standard, contained only Cd. Images from the two resonance tubes were recorded on a photographic plate and their intensities compared by means of intensity marks placed on the same plate. On plotting τZ_Q against the pressure of hydrogen from the data a straight line was obtained and the effective quenching cross section was found to be $\sigma^2_Q = 1.12 \times 10^{-16}$ cm², taking τ as 2.5×10^{-6} sec. The vapor pressure of Cd in the resonance tube was about 5.6×10^{-4} mm, corresponding to a temperature of 210°C. Further work on the quenching by other gases is in progress.

10. Correlation Between Electromagnetic Theory and Wave Mechanics. LLOYD T. DEVORE, *The Pennsylvania State College. (Introduced by W. R. Ham.)*—At the Pittsburgh Meeting of the Society it was shown that on certain assumptions equations, formally identical with those of Schrödinger, followed from the electromagnetic field equations. These assumptions were as follows: (1) The vector potential of the field set up by the accelerated charges vanishes at the nucleus and at the outer boundary of the atom. (2) The energy of the standing waves is quantized by an application of the relation, $E = h\nu$. (3) The mechanical momentum is equal to the electromagnetic momentum within the atom. In the present paper a discussion of the electrodynamics of the Bohr model leads to a discussion and modification of assumption (1) and an interpretation of assumption (2). It is shown that the standing waves referred to are radial and of the same order of magnitude as the de Broglie waves of the electron. All discussion tends to demonstrate the validity of assumption (3).

11. Approximate Atomic Wave Functions for Some Excited States of Helium. W. S. WILSON, *Yale University,* AND R. B. LINDSAY, *Brown University.*—Normalized one electron wave functions and the corresponding fields and energy parameters have been computed by the Hartree self-consistent field method for the following excited states of helium: $(1s)^2$, $(1s)(2s)$, $(1s)(2p)$, $(2s)^2$, $(2p)^2$ and $(2s)(2p)$. In the case of the $(1s)(2s)$ and $(1s)(2p)$ states comparison is made between the total radial charge density and that computed with the use of a variational method by Eckart and Vinti (Phys. Rev. **36**, 878 (1930); **37**, 448 (1931)). The agreement is satisfactory, but seems to show that the self-consistent field method yields results agreeing better in any given case with the singlet than with the triplet state. The total energy value of helium in the $(2s)^2$ state is calculated to be 1.4606 atomic units, corresponding to an energy change of 58.81 volts in the transition $(1s)^2 - (2s)^2$. This is in fairly good agreement with the value of 59.25 $\pm$.12 volts found by Whiddington and Priestley (Proc. Roy. Soc. **A145**, 462 (1934)) as the energy loss in a single collision of an electron with a helium atom and probably indicates the type of transition involved in their experiment.

12. Energy and Angular Momentum in Certain Optical Problems. R. D'E. ATKINSON, *Rutgers University.*—The fact that circularly polarized light exerts a torque $2h/2\pi$ per photon on a half-wave plate on which it falls is shown to have been established by a very old experiment, of which a simplified modification is described. The experiment involves moving interference fringes, and a general condition for obtaining such fringes is enunciated and applied to five other problems. It is concluded that when polarized light is reflected obliquely from a metal mirror revolving in its own plane, the reflection coefficient should be changed by an amount proportional to the angular velocity; that a diffraction grating moving in its own plane should be able to give moving fringes; and that there is considerable support for the view that all photons should be regarded as possessing the same amount of angular momentum, the state of polarization of the light depending on their statistical arrangement.

13. The Spherically Symmetric Field in the Born-Infeld Theory.[1] B. HOFFMANN, *University of Rochester, N. Y.*—Born and Infeld have proposed two sets of field equations[2] for the new field theory and have also suggested a method for including the gravitational field.[3] The most general spherically symmetric field allowed by each set of field equations has been investigated in the present paper and it is shown that each field must be static. The two fields may, with suitable choice of units, be written as:

Case I. $G \neq 0$

$$ds^2 = A dt^2 - A^{-1} dr^2 - r^2(d\theta^2 + \sin^2\theta d\varphi^2),$$
$$F_{14} = \epsilon/(r^4 + \mu^2 + \epsilon^2)^{\frac{1}{2}},$$
$$F_{23} = \mu \sin\theta,$$

where $A = 1 - 2m/r - \frac{1}{3}(1+\lambda)r^2 + (1/r)\int_0^r (r^4 + \mu^2 + \epsilon^2)^{\frac{1}{2}} dr$,

and

Case II. $G = 0$

$$ds^2 = A dt^2 - A^{-1} dr^2 - r^2(d\theta^2 + \sin^2\theta d\varphi^2),$$
$$F_{14} = \epsilon(r^4 + \mu^2)^{\frac{1}{2}}/r^2/(r^4 + \epsilon^2)^{\frac{1}{2}},$$
$$F = \mu \sin\theta,$$

where

$$A=1-2m/r-\tfrac{1}{3}(1+\lambda)r^2+(1/r)\int_0^r((r^4+\mu^2)(r^4+\epsilon^2))^{\frac{1}{4}}/r^2\cdot dr.$$

Each field corresponds to a particle of charge ϵ and magnetic pole strength μ. If isolated magnetic poles are allowed, the second field has an infinity at the pole that is avoided by the first field.

[1] Sent to the Oxford Quarterly Journal under the title, *On the Spherically Symmetric Field in Relativity, III.*
[2] Proc. Roy. Soc. **A144**, 425 (1934), Eqs. (2.15) and (2.28), respectively.
[3] Ibid. p. 435.

14. Huygen's Principle and the Lorentz Contraction Hypothesis. N. GALLI-SHOHAT, *Rockford College, Rockford, Illinois.*—From the application of Huygen's principle to the reflection of light from a moving mirror follows (E. Kohl, Ann. d. Physik **28**, 259 (1909)), that the relative ray—the ray observed by a moving observer—deviates in the second order from the ordinary law of reflection. The angle of deviation $\Delta\varphi=(v^2/c^2)\cos^2\varphi\sin 2\theta_N$, here φ is the angle of incidence of the relative ray, θ_N– the angle which perpendicular to the mirror makes with the direction of velocity v, c—velocity of light. If we now introduce into consideration the Lorentz contraction, we can see that the angles θ_m, θ_r, respectively, which the mirror and the telescope (two openings) make with the direction of motion change with respect to the ether by an amount $\Delta\theta_m$, θ_r which is found to be:

$$\Delta\theta_m=\tfrac{1}{4}(v^2/c^2)\sin 2\theta_m, \qquad \Delta\theta_r=\tfrac{1}{4}(v^2/c^2)\sin\theta_r.$$

Combining this with Huygen's principle, we found the resulting deviation from the law of reflection to be:

$$\chi=\Delta\varphi-2\Delta\theta_m-\Delta\theta_r=\tfrac{1}{2}(v^2/c^2)\cos 2\varphi\sin 2\theta_N-\tfrac{1}{4}(v^2/c^2)\sin 2\theta_r.$$

This shows that the Lorentz contraction does not compensate the second order effect due to Huygen's principle, as would be expected according to the theory of relativity.

SATURDAY MORNING AT 10:00 O'CLOCK

Room 401

(For simultaneous session of the Optical Society, Room 428, see Program, pages 6–7.)

15. On the Emission of Protons by Samarium. J. A. BEARDEN AND W. R. KANNE, *Johns Hopkins University.*—In a study of the radioactivity of samarium (Phys. Rev. **45**, 743 (1934)), the range of the emitted α-particle was determined by using a thin source made from samarium oxide. In this work only one type of ionizing particle was observed. However Mäder (Zeits. f. Physik **88**, 601 (1934)) also found an emitted proton of ionizing power equal to about one-half that of the α-particle. The resolving power of the apparatus as used above was such that one could not definitely exclude the possibility of a proton emission. The apparatus has been improved and a thin source has been obtained by using samarium chloride dissolved in alcohol. The resolving power is such that two groups of α-particles which differ in range by 2 mm can be detected. From the measurement of more than 2100 particles emitted by samarium there is still no evidence of a particle of an ionizing power equivalent to that found by Mäder. This is in agreement with the results of Ortner and Schintlmeister (Zeits. f. Physik **90**, 698 (1934)). It is possible that the apparent particle group found by Mäder was due to columnar ionization (D. Lyford, Thesis, Johns Hopkins University, 1934).

16. Absorption and Scattering of Slow Neutrons. J. R. DUNNING AND G. B. PEGRAM, *Columbia University.*—Experiments on the low velocity neutrons, shown by Fermi and his colleagues to be most effective in many cases in producing artificial radioactivity, indicate that few if any of such slow neutrons have sufficient energy to permit detection by a paraffin front ionization chamber-amplifier system. Cd, which has an extraordinary nuclear cross section for collision with slow neutrons, does not show unusual cross section for neutrons detected through projected protons. To measure the intensity of slow neutron radiation, it is convenient to count the ionizing particles coming from a film of lithium under the action of slow neutrons. The absorption and scattering, as compared with high energy neutrons, of slow neutrons from a Radon-Be source in the center of a paraffin sphere have been studied. Most of the elements used as absorbers show no marked difference as between fast and slow neutrons. Besides cadmium, boron and mercury as noted by Fermi and his colleagues, tungsten shows a marked specific absorption for these slow neutrons. The effect of the size of the paraffin sphere surrounding the neutron source on the number of slow neutrons affecting the lithium film at a distance of 25 cm from the source, was measured by the absorption produced by a screen of Cd 1 mm thick. Above a certain region, the increase in number of slow neutrons is not large, since with a paraffin sphere of 6.2 cm radius surrounding the source, 23 neutrons per minute were in the absorption range of Cd, with a sphere of 10.1 cm radius, 26 neutrons per minute, and with a 12.7 cm radius sphere, 28 neutrons per minute.

17. The Capture and Scattering of Neutrons. H. A. BETHE, *Cornell University.* (*Introduced by R. C. Gibbs.*)—Recent experiments show that many heavy elements can be disintegrated by neutrons and the disintegrative cross section increases with decreasing neutron velocity. This evidence together with chemical evidence and theoretical considerations suggest neutron capture by the nucleus, the surplus energy being radiated. The maximum observed

cross section for Ag, referring to neutrons with kinetic energy kT, is 2×10^{-22}. Theoretically, the cross section for radiative capture is

$$\Phi_{\text{rad}} = \pi^2 \frac{(e')^2}{mc^2} \frac{\hbar}{mc} \frac{\hbar}{E} \hbar\omega \frac{df}{dE}, \quad (1)$$

where E is the kinetic energy of captured neutron, $\hbar\omega$ the radiated energy, m and e' the effective mass and charge of the nucleus. df/dE is the oscillator strength of the transition from free to bound state per unit energy. For interaction between neutron and nucleus, the potential probably decreases faster than $1/r^2$ and df/dE decreases as $(E/E_0)^{\frac{1}{2}}$ for E small. E_0 is a critical energy such that for $E<E_0$ the W K B solution is invalid. E_0 is determined by the form of the potential and is zero for slowly decreasing potential. When the W K B method is applicable (a) for all E, the elastic scattering cross section is

$$\Phi_{\text{el}} \sim \pi\hbar^2/mE \quad (2)$$

and $\Phi_{\text{el}}/\Phi_{\text{rad}} \sim 10{,}000$, if $\hbar\omega df/dE$ be taken as unity, but experimentally $\Phi_{\text{el}}/\Phi_{\text{rad}} \sim 1$; (b) for $E>E_0$ then $\Phi_{\text{el}}/\Phi_{\text{rad}} \sim 10{,}000(E/E_0)^{\frac{1}{2}}$, which is much smaller than for case (a). Attributing the cross section 2×10^{-22} obtained from absorption measurements of neutrons in Ag as that of elastic scattering, E_0 is about 10,000 volts, and taking $E=kT = 1/40$ volt then $\Phi_{\text{el}}/\Phi_{\text{rad}} \sim 15$. The magnetic interaction between neutron spin and nuclear motion would be ten times too small to account for the observed effect; furthermore this interaction should be zero if the angular momentum of the neutron vanishes as it must when the probability of scattering and capture is large.

18. Alpha-Particle Scattering by Deuterons and Protons. HENRY MARGENAU AND ERNEST POLLARD, *Yale University.*—If alpha-particles impinge on matter the yield of scattered nuclei first diminishes according to the $1/V^4$ law until anomalous scattering sets in. From the energies at which anomalous scattering occurs it is possible to estimate the distance at which the classical law of force between the nucleus and alpha-particle breaks down. Experiments have been carried out to determine the energy at which anomalous scattering is observed for alpha-particle collision with deuterons and protons. The results on protons confirm the work of Chadwick and Bieler and show that anomalous scattering is detected at the range of a 1.7 cm alpha-particle (for direct impact). A corresponding rise for deuterium was observed at an alpha-particle range of 1.3–1.6 cm. The distances between nuclei at which anomalous scattering is detected are:

Proton—alpha-particle $= 4.6\times10^{-13}$ cm.
Deuteron—alpha-particle $= 3.1\times10^{-13}$ cm.

19. Proportional (Geiger-Klemperer) Nuclear Particle Counter, and Attempts to Detect Deuterons from Two Favorable Reactions. WILLIAM W. EATON AND ERNEST POLLARD, *Yale University.* (*Introduced by A. F. Kovarik.*)—An account is given of the development and of some applications of a proportional counter for detecting highly-ionizing nuclear particles. As compared with linear counters depending on high gain amplifiers, the new counter is free from electrical interference. A search for deuterons of 8 cm range from the reaction of 3.9 cm α-particles with nitrogen, stimulated by a suggestion of F. Perrin, was unsuccessful. No group of particles with 4 to 10 cm range was found except a group of protons, due to resonance, at 6 cm. That these were protons was checked by magnetic deviation. Another possible nuclear reaction: ${}_5B^{10} + {}_2He^4 = {}_6C^{12} + {}_1D^2$, would be expected to yield 16 cm range deuterons. Heidenreich reports a group of particles of about this range. No group of deuterons greater than 25 percent of the natural proton background was here detected. In the course of the magnetic deviation experiments, the particles resulting from the bombardment of material containing deuterium were shown by direct comparison to have a mass of about twice that of a proton.

20. Heights of Nuclear Potential Barriers. ERNEST POLLARD, *Yale University.* (*Introduced by A. F. Kovarik.*)—An attempt has been made to use the available data on disintegration and anomalous scattering using alpha-particles, to estimate the energy of the nuclear barrier tops. If the minimum disintegration or anomalous scattering energies given by various workers are assumed to correspond to a penetration of 10 percent and the Gamow penetration formula holds for these energies an allowance can be made for penetration which yields values for the barrier heights which should show their behavior. It is found that while the uncorrected minimum energies vary linearly with Z, to a first approximation, the corrected values behave differently, being governed by the rule that the cube of the radius at the summit is proportional to the atomic weight. The numerical values found are in good agreement with estimates of nuclear radii made by Dunning, Eastman and Gamow and it is suggested that the rule governs all nuclei (again to a first approximation). Hydrogen does not fit the line and this is linked with the fact that known proton barriers do not obey the same rule. It is suggested that where there is equality of neutron-proton content a second order force alone operates between particles but that an isolated neutron or proton is subject to a first order field which extends farther from the nucleus. Potentials A/r^6 (first order); B/r^{12} (second order) would serve to explain the data.

21. Acceleration of Electrons to High Energies. HERBERT TROTTER, JR., AND J. W. BEAMS, *University of Virginia.*—The method of accelerating electrons to high energies without the use of extremely high voltages (Phys. Rev. **45**, 849 (1934)) has been improved and extended. An initial potential of 4.5×10^4 volts was increased to 5.4×10^5 volts by a Marx circuit. This was then applied impulsively by an overvolted vacuum spark gap to seven transmission lines. The first line terminated in a pointed wire while the ends of the remaining lines were attached each in succession to properly spaced hollow cylindrical electrodes mounted co-axially with the wire in an evacuated glass tube 400 cm long. The lines were adjusted so that the times of arrival of the electric impulses at the respective electrodes in the tube were such as first to pull electrons out

of the pointed wire and then accelerate them between each successive pair of electrodes. The maximum energy of the electrons as determined by their deflection in a magnetic field was roughly 2.5×10^6 volts. A vacuum spark gap supplied with impulsive potentials of 2×10^5 volts at the rate of 800 per sec. by a Marx circuit, the gaps of which were quenched by air jets, was found to function satisfactorily. Hence, when requisite power is available, the method should be capable of giving high speed particles in considerable numbers.

Saturday Morning at 10:00 o'clock

Room 329

(For simultaneous session of the Optical Society, Room 428, see Program, pages 6–7.)

Paper No. 25 will be read by title.

22. Band Spectra of Beryllium Deuteride. Philip G. Koontz, *Yale University.* (*Introduced by Wm. W. Watson.*)—Spectrograms of the $^1\Sigma\rightarrow{}^1\Sigma$ BeD^+ bands in the region λλ2200–3100 have been taken on a Hilger E1 spectrograph and the $^2\pi\rightarrow{}^2\Sigma$ BeD bands at λ4990 have been photographed in the third order of a 21-foot grating. Rotational analysis of seven BeD^+ bands gives $B_e'=3.9712$, $\alpha'=0.0578$, $B_e''=5.955$, $\alpha''=0.1233$. By using Bengtsson's value of $B_e''=10.813$ for the BeH^+ system, $\rho^2=B_e^{i\prime\prime}/B_e''=0.55073$. The ratio of the reduced masses gives this identical value. The vibrational equation

$$\nu_0=39{,}416.2+1096.4(v'+\tfrac{1}{2})-8.5(v'+\tfrac{1}{2})^2-0.16(v'+\tfrac{1}{2})^3-[1647.6(v''+\tfrac{1}{2})-21.9(v''+\tfrac{1}{2})^2-0.06(v''+\tfrac{1}{2})^3]$$

is found, giving an electronic isotope shift of 0.8 cm^{-1}. Rotational analysis of the BeD (0,0) and (1,1) bands gives $B_e'=5.7583$, $\alpha'=0.131$, $B_e''=5.6807$, $\alpha''=0.122$. Using Olsson's value of $B_e''=10.308$ for BeH, we have $\rho^2=B_e^{i\prime\prime}/B_e''=0.55110$, whereas calculation from atomic masses gives $\rho^2=0.55073$, an increase of 0.07 percent. The identity of the ratio of the B_e's and of the ratio of reduced masses in the ultraviolet bands, and the difference of the two values in the green bands agrees with predictions by Kronig that in certain cases the potential energy functions are not the same for the two isotopic molecules. The Λ-doublings of the BeD and BeH bands are compared.

23. The Infrared Absorption Spectrum of Methyl Deuteride. Nathan Ginsburg and E. F. Barker, *University of Michigan.*—The vibration-rotation interaction in normal methane makes it impossible to obtain directly from the observed bands the moment of inertia and molecular dimensions. The replacement of one of the H atoms by deuterium reduces the degeneracy, and gives rise to six fundamental frequencies of which three are single and three are double. The corresponding bands have all been observed. Of the three parallel type bands, two lie very close to the bands of normal methane and are difficult to separate completely. The one at 2205 cm^{-1}, however, is well isolated and has been completely resolved. It yields a value of 7.166×10^{-40} g cm^2 for the moment of inertia about an axis perpendicular to the symmetry axis of the molecule, and this determines the interatomic distances, which are $C-H=1.093\times10^{-8}$ cm and $H-H=1.785\times10^{-8}$ cm. The moment of inertia about the axis of symmetry, which must be equal to that of normal methane, is then determined as 5.298×10^{-40} g cm^2.

24. Ultraviolet Absorption Spectra of the Deutero-Ammonias. W. S. Benedict, *National Research Fellow, Princeton University.*—Spectrograms of ammonia samples containing varying amounts of deuterium have been obtained over a considerable range of temperature and pressure. A vibrational analysis has been made for each of the molecules NH_3, NH_2D, NHD_2 and ND_3. Some bands in ND_3, those ending on the zero vibrational level of the upper electronic state, show discrete rotational structure: the zero levels of the other isotopic molecules, by virtue of their greater zero-point energy, lie above the predissociation limit and are diffuse. A partial rotational analysis of the discrete bands agrees with the vibrational analysis in showing the upper state to have the equilibrium configuration of a plane equilateral triangle, and gives $r_{0N-H}=1.07$A. Potential functions may be calculated for both states which account for the observed isotope shifts.

25. Bands of BF Excited by the Electrodeless Discharge. Herbert M. Strong and H. P. Knauss, *Ohio State University.*—The molecules N_2, CO and BF have identical numbers of electrons, and similar mass, but different symmetry. A search has been made for BF bands by exciting BF_3 gas in the electrodeless discharge. Very pure BF_3, furnished by Booth and Willson of Western Reserve University, was sealed off in a Pyrex tube with a thin window transparent to ultraviolet light, and the spectrum was obtained with a Hilger El spectrograph. The bands obtained show a marked resemblance to those of CO, but with the subheads somewhat closer together. Observed bands include those reported by Tawde and Johnson (Phil. Mag. **13**, 501 (1932)), and bands at 3392–3399 and 3250–3257A found recently by Mulliken and Dull (private communication). The following new bands are obtained: 3118–3121, 3355–3364, 3506–3510, 3545–3550, 3558–3567 and 3709–3716A. Observations are in progress with a 21-foot grating spectrograph. The BF_3 gas cleans up rather rapidly in the tube during the discharge, thereby making it difficult to obtain the necessary long exposures.

26. Band Systems of MgCl, CaCl and SrCl. ALLAN E. PARKER, *Columbia University.*—A vibrational analysis has been made of band systems due to MgCl, CaCl and SrCl. There are two systems due to MgCl with $\nu_E = 26{,}441.5$, $\omega' = 474.8$ and $\omega'' = 447.4$ for the more intense system and $\nu_E = 25{,}887.2$, $\omega' = 466.9$ and $\omega'' = 447.4$ for the less intense system. CaCl has three extensive systems with $\nu_E = 16{,}093.5$, $\omega' = 367.1$, $\omega'' = 364.5$; $\nu_E = 16{,}850.6$, $\omega' = 361.0$, $\omega'' = 364.0$; $\nu_E = 26{,}498.9$, $\omega' = 336.0$, $\omega'' = 368.3$, respectively. There are also three weakly developed systems. Two strong systems of SrCl are observed with the respective constants $\nu_E = 15{,}716.9$, $\omega' = 306.3$, $\omega'' = 301.6$ and $\nu_E = 25{,}401.7$, $\omega' = 279.3$, $\omega'' = 298.9$. SrCl has three poorly defined systems as well. The isotope effect due to Cl^{35} and Cl^{37} is observed in all transitions. The rotational structure is partially resolved for most systems, and in the ultraviolet CaCl bands sufficiently to estimate that $B' = 0.24$ and $B'' = 0.26$. The electronic states and dissociation products will be discussed. All values are expressed in cm^{-1}.

27. Ultraviolet I_2 Fluorescence. DANA T. WARREN, *Yale University.*—Ultraviolet fluorescence spectra have been taken and measured microphotometrically under various conditions. The McLennan bands at wavelengths below λ2400 are overlaid by fine structure, as reported by Loomis and Allen. Vibrational analysis of this shows that it consists of fluorescence series, belonging to absorption chiefly from the $v'' = 0$, 1, 2 levels of the ground state, and joining onto Oldenberg's single resonance series. Both Hg and Al excitation show closely similar spectra. The resemblance of this spectrum to that found by Asagoe in an electric discharge indicates that the latter is also a resonance spectrum, as he suggests. The diffuse McLennan bands fall into two series divided at about λ3340. These series show remarkable similarity in their variation with excitation conditions. Fluorescence shows the short wavelength series more completely resolved (presumably because of limitation of J values) than does the electrical discharge. Comparison of the two systems shows that each unexpectedly has vibrational intervals falling into two similar well-defined groups; the intervals in each system alternate between the two values for a part of their range. This similarity must be due to the lower state, the difference in upper state being indicated by the difference in relative intensity of the systems in different emission sources.

28. Anomalous Intensity Distribution in Spectra Given by Certain Ruled Diffraction Gratings. R. W. WOOD, *Johns Hopkins University.*—Further study has been made of the gratings reported at the Pittsburgh meeting which give polarized spectra in which a fifteen-fold increment of intensity occurs within a spectral range of 100A. These very remarkable cases should be of interest to members familiar with Lord Rayleigh's dynamical theory of the diffraction grating. Grating replicas made by a new process will also be shown.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 401

(For simultaneous session of the Optical Society, Room 428, see Program, pages 7–9.)

Paper No. 36 will be read by title.

29. The Enhancement of Cosmic-Ray Nuclear Bursts by the Presence of Subsidiary Material. C. G. MONTGOMERY, D. D. MONTGOMERY AND W. F. G. SWANN, *Bartol Research Foundation of the Franklin Institute.*—Cloud chamber experiments by G. L. Locher suggested that radiations from a primary burst possessed the power to stimulate secondary, and perhaps tertiary bursts, so that it should even be possible to initiate bursts in a body B by action of the radiation stimulated in another body A by the primary radiation. Under such conditions, the frequency of bursts produced in the wall of an iron chamber over which is placed a water tank should depend upon the amount of water, increasing with the thickness of the water up to a point where the absorption of the primaries compensates the effect. The writers have performed the experiment cited, using an iron sphere of 14.2 liters capacity and 2.5 cm wall thickness, placed 75 cm below a tank 126 cm in diameter and 150 cm high. It was found that the number of bursts of all sizes greater than 0.5×10^6 ions increased with the thickness of the water, attaining at a thickness of 79 cm a value 20 percent greater than the value at zero thickness, but a value equal to the initial value at 136 cm of water. That the secondary bursts referred to are produced in the iron is guaranteed by the fact that the substitution of a magnesium sphere for the iron one eliminates the phenomenon.

30. Evidence for a Positron-Negatron Component of the Primary Cosmic Radiation. THOMAS H. JOHNSON, *Bartol Research Foundation of the Franklin Institute and the Carnegie Institution of Washington.*—Recent coincidence counter measurements at several stations have shown that (1) cosmic ray showers (events in which two or more rays emerge simultaneously from a lead plate) are more intense relative to the total radiation at high elevations, (2) high elevation (4300 m) shower intensities have about the same latitude effect as the total radiation, (3) sea level showers have little, if any, latitude effect above 29°, (4) high elevation showers at latitude 29° are almost completely symmetric with respect to the meridian plane, (5) sea level

showers at the equator are slightly asymmetric favoring the west. These facts are accounted for on the hypotheses (1) high elevation showers are produced principally by positron-negatron primary rays (latitude effect but no asymmetry) and (2) the asymmetry in the total radiation is produced by more penetrating positives, presumably protons, which also produce enough of the showers at sea level to account for the slight asymmetry at the equator. The negative component which is thus introduced seems now to be required to harmonize asymmetries and latitude effects in the light of new calculations of Lemaitre, Vallarta and Bouchaert. The hypotheses to which these facts lead are similar to those proposed on other grounds by Compton and Bethe.

31. The Absorption of Cosmic-Ray Electrons in Lead. R. H. WOODWARD AND J. C. STREET, *Harvard University.*—The validity of Rossi's counter observations of the penetration of cosmic-ray electrons through lead has been questioned on two counts—(1) uncertainty of the contribution of electron showers and (2) failure of the results to agree with the energy distribution and specific energy loss measurements of Anderson. A test of the first point has been made with a four counter unit so spaced that 90 cm of lead could be introduced between the counters. Additional counters connected as a hodoscope unit (Johnson and Stevenson, J. Frank. Inst., V. **216**, 329 (1933)) controlled by the coincidence set were placed adjacent to the coincidence counters in order to detect any showers scattered from the beam or coming in from the sides. In only 10 percent of the coincidences do the hodoscope counters detect any associated ray. This result is the same with and without the lead. These observations show that the first objection is not important. As a test of the second point accurate data on the absorption curve up to 90 cm of lead have been obtained. These observations have been compared with Anderson's energy distribution (for the counter controlled data) to determine what specific energy loss values for electrons in lead must be assumed to satisfy both sets of data. The results are given in the table.

Average energy loss (m.e.v.) per cm Pb	45	31	25	20
Energy range (m.e.v.)	0–680	680–1150	1150–1900	1900–2500

32. Nature of the Penetrating Cosmic Radiation at Sea Level. E. C. STEVENSON AND J. C. STREET, *Harvard University.*—Three counters were placed in a vertical plane with a 22 cm cloud chamber between the lower two and the upper two so spaced that lead up to a thickness of 45 cm could be inserted between them. A coincidence circuit for the three counters controlled the chamber. This arrangement permits a study of the mechanism of coincident counter discharges. Forty-four photographs were taken with 45 cm and 48 with 15 cm of lead, respectively, between the upper counters. In the first case 39 pictures showed single straight tracks directed in a line through the three counters and the intervening lead. One had two such tracks, three had sharply inclined straight rays and the last had only two weak beta-rays. With 15 cm of lead the numbers falling in these categories were 42, 2, 3 and 1, respectively. In the first case 24 of the photographs having single rays showed contemporary secondary phenomena such as one or two sharply inclined straight tracks or soft electron tracks. In the second case there were 29 such occurrences. Summed up these results are strong evidence that at least 90 percent of the coincident counts for such an arrangement are directly due to the passage of single electrons through the apparatus.

33. A Two-Crystal Transmission Spectrometer for Ultra-Short X-Rays. T. R. CUYKENDALL AND M. T. JONES, *Cornell University.*—A brief description, with sample data obtained, is given of a 600,000 volt x-ray plant. The potential, obtained from two induction coils, is applied across the two sections of a large x-ray tube evacuated with apiezon oil pumps. The size and the position of the focal spot are adjustable by a "magnetic lens" and sylphon bellows, respectively. The target is cooled with ice water circulated by an air bubble hoist. The complete system is operated by remote control from a lead house. A sphere gap measures peak voltage, a generating voltmeter of the Kirkpatrick type indicates relative values. The design of a direct-reading two-crystal spectrometer for use in the region $0.03<\lambda<0.20$ is described. The need for long crystal faces is avoided by placing the crystals directly in the path of the beam, so that the "transmission method" is employed. The crystals are 123 cm apart; enabling the second crystal to be shielded from the direct beam. The ionization chamber, containing argon at 80 atmospheres, has been found linear over the range of intensities observed. The calibration of the spectrometer and the elimination of the background are discussed. A resolution of 28 at 0.05A is obtained with the crystals used.

34. Absorption of X-Rays in the Wavelength Range 50 X.U. to 200 X.U. M. T. JONES AND T. R. CUYKENDALL, *Cornell University.*—Absorption coefficients for x-rays in the wavelength range $50<\lambda<200$ X.U. have been measured for the following elements: C (6), Na (11), Al (13), K (19), Ni (28), Cu (29), Cb (41), Mo (42), Ag (47), Sn (50), Ta (73) and Pb (82). The Klein-Nishina formula for σ, the absorption coefficient due to scattering, gives within 1 percent the observed absorption coefficients in carbon for the region $40<\lambda<100$ X.U.; and in sodium for the region $50<\lambda<70$ X.U. The observed absorption coefficients in aluminum are higher than σ by 2.5 percent at 50 X.U. and by 22 percent at 140 X.U. Assuming the correctness of the Klein-Nishina formula for σ, the photoelectric absorption τ is calculated from $\mu=\tau+\sigma$, where μ is the observed total absorption coefficient. τ is less than 10 percent of μ in sodium for $\lambda<110$ X.U.; in aluminum for $\lambda<100$ X.U.; and in potassium for $\lambda<70$ X.U. The photoelectric absorption for an element of atomic number Z may be expressed empirically by $\tau=K\lambda^{\alpha}Z^{\beta}$, where K is a constant. For elements from Ni (28) to Pb (82), α decreases from about 2.9 to 2.6. For elements from Cb (41) to Pb (82), β decreases from about 3.85 to 3.5 as the wavelength increases from 50 X.U. to 140 X.U.

35. Calculation of the X-Ray Energy Level Widths of Au (79). E. RAMBERG AND F. K. RICHTMYER,[1] *Cornell University.*—The natural width of any energy level of an atom is given by the reciprocal lifetime of the corresponding state which in turn is equal to the sum of the transition probabilities to all states of lower energy plus the probability of the radiationless dissociation of the atom into an ion and free electron (Auger effect). To compare theoretical expectation with measurements on Au (79) reported by S. W. Barnes and the authors (Phys. Rev. **46**, 843 (1934)), wave functions were calculated for electrons moving in the Fermi-Thomas field of Tl $(81)^{++}$; by use of these functions, the coordinate matrix elements and Coulomb interaction integrals were computed to determine the probabilities of the emission of dipole and quadrupole radiation and of the occurrence of Auger effects, respectively. Preliminary numerical results are given; they indicate that the Auger effects are responsible for the relatively large width of the levels of high total quantum number as well as for the greater width of levels with small azimuthal quantum number.

[1] Grateful acknowledgment is made to the American Philosophical Society for a grant-in-aid of this research. F. K. R.

36. X-Ray Wavelength Scales. ARTHUR E. RUARK, *University of North Carolina.*—Experiments of Bearden and of Bäcklin strongly support the ruled-grating scale of x-ray wavelengths, and indicate that crystal wavelengths differ from them by a constant factor, due to the use of an incorrect value of the calcite grating space. Now, acceptance of ruled-grating wavelengths implies that $e=(4.805\pm0.003)\times10^{-10}$ e.s.u. If we employ this value, and the e/m value of Shane and Spedding, $(1.759\pm0.0003)10^{7}$ e.m.u./gram, then the puzzling discrepancy between measured and calculated energies of photoelectrons, discussed in a paper by the writer (Phys. Rev. **45**, 827 (1934)), is entirely removed.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 329

(For simultaneous session of the Optical Society, Room 428, see Program, pages 7–9.)

37. The Size and Arrangement of Bismuth Micro-Crystals Formed from Vapor. C. T. LANE, *Yale University. (Introduced by L. W. McKeehan.)*—The magneto-resistance of films of bismuth, deposited on glass and mica, has been measured at room and liquid-air temperatures and for various angles between the film normal and the magnetic field ($H=16{,}000$). The ratio $\Delta R_{-180}/\Delta R_{+20}$ rises steeply for thicknesses between 0.1μ and 0.4μ and then much more gradually to a thickness of 4μ. The thermal coefficient of resistance shows no corresponding anomaly. X-ray analysis shows all the films to be composed principally of small crystals with (111) parallel to the backing. ΔR varies with the direction of H, the current remaining always in one direction in the film, approximately as predicted, from experiments on monocrystals for such an assembly. It is suggested that at a thickness of 0.4μ the micro-crystals first attain a normal distribution of sizes.

38. The Crystal Structure of Cuprous Ferrite. WALTER SOLLER AND A. J. THOMPSON, *University of Arizona.*—Because of the importance of copper ferrites in metallurgy, several forms of copper ferrites were produced by heat treatment and studied. One form was found to be only slightly magnetic compared with the highly magnetic cubic form of cupric ferrite. Chemical analysis showed this form had the formula $CuFeO_2$. X-ray diffraction patterns and photo-densitometer charts were obtained of this cuprous ferrite. The charts were analyzed, and the intensities of the lines were determined by the method described in the paper given by Soller at the Berkeley meeting, June, 1934 (Phys. Rev. **46**, 331 (1934)). $CuFeO_2$ was found to have a rhombic lattice with unit cell dimensions, $a=5.96$A, $\alpha=29°\,26'$ and one molecule to the cell. The rhombic coordinates of the atoms were as follows: Cu (0, 0, 0); Fe (1/2, 1/2, 1/2); O (1/9, 1/9, 1/9) and (−1/9, −1/9, −1/9). Cuprous ferrite belongs, therefore, to space symmetry group D^5_{3d}.

39. Electric Impedance of Muscle. KENNETH S. COLE, *Columbia University,* AND EMIL BOZLER, *University of Pennsylvania.*—A muscle is assumed to be a homogeneous random suspension of parallel fibers in an electrolyte, and each fiber to be a circular cylinder of electrolyte surrounded by a thin poorly conducting membrane. The expressions derived for the resistance and reactance normal to the fiber axes are similar to those previously given for suspensions of spherical cells, and involve the resistances of the external and internal electrolytes, the resistance and reactance of the membranes, and the volume concentration and diameter of the fibers. From measurements of the resistance and capacity of the relaxed frog sartorius muscle at frequencies from 10^3 to 10^6 cycles per second, it is found that the fiber membrane has a complex polarization impedance of the form, $z=z_1(i\omega)^{-\alpha}$, where $i=\sqrt{-1}$, $\omega=2\pi$ times the frequency, $\alpha=0.79$, and $z_1=1.35\times10^5$ ohms/cm^2. Although the volume concentration of fibers is difficult to determine, it is indicated that the membrane has an ohmic resistance of about 40 ohms/cm^2, and that the internal fiber resistance is 260 ohm cm or about 3.5 times that of the external medium. In a rigor similar to normal contraction the volume concentration, internal resistance, and membrane polarization exponent, α, are unchanged while the membrane resistance and polarization impedance, z_1, increase.

40. The Viscosity of Deuterium. H. C. TORREY, *Columbia University.*—In view of the considerable difference between the effective collision cross sections of the hydrogen isotopes as measured by the molecular beam method, a comparison of the cross sections effective in viscosity has been made. The method employed was first used by A. O. Rankine (Proc. Roy. Soc. **A83**, 265 (1910)) to measure the viscosities of the inert gases. A falling mercury pellet drives the gas through a capillary tube, the time of fall between two given points being proportional to the coefficient of viscosity. The observations were carried on at room temperatures. As a check on the viscosimeter the viscosity of H_2 was measured relative to dry air, the result checking Yen's generally accepted value (Phil. Mag. **38**, 582 (1919)) within one percent. The ratio of the viscosity of D_2 to that of H_2 as determined by this method is 1.410 ± 0.03. By using Yen's value, this gives for the viscosity of D_2 at 23.0 C: 124.4 ± 2.5 micropoise. According to simple kinetic theory, the viscosity of a gas varies directly with the square root of the mass and inversely with the collision cross section of a molecule. Consequently the above result shows that the molecular cross sections of the hydrogen isotopes effective in viscosity differ by less than two percent.

41. Scattering of Potassium and Sodium Atoms in Various Gases. S. ROSIN AND I. I. RABI, *Columbia University.*—Narrow beams of neutral potassium and sodium atoms were scattered by traversing a limited region containing the scattering gas in question. The mean free path and consequently the collision cross section were evaluated from the reduction in the intensity of the beam when the gas was introduced into its path. Geometrical conditions were such that atoms deviated through an angle of one minute of arc or more were counted as scattered. The results for the effective collision radii and cross sections are shown in Table I. A striking result of this experiment is the considerable difference in the collision cross sections for hydrogen and deuterium gas. This effect is much more marked in the case of potassium where the collision cross section is 30 percent larger for deuterium than for hydrogen, while the excess amounts to 18 percent in the scattering of sodium.

TABLE I.

Gas	Collision Radius σ_{12} (A) Potassium	Sodium	Cross Section $\pi\sigma_{12}^2$ (A^2) Potassium	Sodium
H_2	7.47	7.01	175	154
D_2	8.54	7.62	229	182
He	7.25	6.44	165	130
Ne	9.10	8.24	260	213
A	13.6	11.3	581	402

42. Fluidity and Molecular Complexity. EUGENE C. BINGHAM AND CHARLES E. COOMBS, *Lafayette College.*—Numerous attempts have been made to connect the fluidity (or viscosity) of liquids with temperature or pressure as by means of the Batschinski relation. Fewer attempts have been made to relate fluidity to molecular complexity, through atomic constants of one kind or another. We propose for normal organic compounds a new relation $\log (F/\varphi) = AN + B \cdots$ complexity formula (1), where F is the free volume already familiar from Batschinski's study, N is the number of methylene groups in a straight chain of a homologous series, and A and B are constants. If substances are compared at equal free volume, the above equation becomes $\log \eta = AN + C \cdots$ viscosity-complexity formula (2), where $C = B - \log F_0$. If, on the other hand, the fluidity is kept constant, a third new reaction is $\log F = AN + D \cdots$ free volume-complexity formula (3), where $D = B + \log \varphi_0$. If, however, the equation is applied to a single compound, $N = N_0$ and $\varphi = KF \cdots$ fluidity-free volume formula (4), which is the Batschinski equation where $\log K = AN_0 + B$. The authors will prove these formulas by using data for various classes of compounds.

43. Equations for Diffusion of Gases Through Metals. W. R. HAM, *The Pennsylvania State College.*—In determining the general equations for diffusion of gases through metals the fundamental flow equation from the kinetic theory of gases, *viz.*,

$$dm/dt = p(m/2\pi KT)^{\frac{1}{2}} e^{-b/T}$$

may be applied in succession to ingoing surface, to the body of the metal and to the outgoing surface. Since in a steady state the rates at all points are equal, this gives a general equation for diffusion provided one expresses the relation between concentrations (or pressures) on the outside and inside and also the variation of concentration (or pressure) with distance on the inside. The latter is difficult to obtain from theoretical considerations. An empirical relation that fits existing experimental data is $p_x = p_1(1 - e^{-a/x})$, where p_x is the pressure at depth x and p_1 the pressure just inside the incoming side. A solution of the three simultaneous equations gives

$$dm/dt = \{A_0 p_0^{\nu}(1 - e^{-a/x}) - A_0 p_3^{\nu} - dm/dt(1 - e^{-a/x})(m/2\pi KT)^{\frac{1}{2}} e^{-b/T}\}(m/2\pi KT) e^{-b/T}.$$

Since the third term in the bracket is exceedingly small compared with the other two and since the second is usually made small or corrected for in diffusion experiments, one obtains

$$dm/dt = A p_0^{\nu}(1 - e^{-a/x})(m/2\pi KT)^{\frac{1}{2}} e^{-b/T},$$

which may be written to a first approximation $dm/dt = (B p_0^{\nu}/x) T^{-\frac{1}{2}} e^{(-b+\Delta w)/T}$ and this, except for the $T^{-\frac{1}{2}}$, is the Richardson equation. Several similar methods leading to the same result are discussed.

44. The Diffusion of Hydrogen Through Highly Degassed Palladium. J. D. SAUTER AND W. R. HAM, *The Pennsylvania State College.*—A 30 mil sheet of palladium was heat treated for over a month until readings of rates of diffusion at pressures from 1 cm to 74 cm could be reproduced between temperatures of 180°C and 800°C. The isothermals are exceedingly straight if log rate is

plotted against log p except for the lowest values of p for high temperatures and except for increasingly high values of p for low temperatures. The slope varies from 0.535 to 0.5 but goes through a maximum of about 0.585 at 248°C. This residual and variable excess above 0.5 is probably due to the presence of a small amount of unremoved nitrogen in solution in the palladium. The deviations of the isotherms from a straight line at low temperatures and pressures seem predicted in the general formula as derived by one of us. We have yet to find a case in measurable diffusion in which the variation of adsorption on the ingoing surface is sufficient to affect the rate of diffusion.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member one only of these will be assigned a place on the regular program while the others will be placed in a supplementary program to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for only at the session indicated.